EE 132A
Homework 2 Solutions

Problem 1. Proakis & Salehi 3.1.

Solution: The modulated signal is

$$\begin{aligned}
u(t) &= m(t)c(t) = Am(t)\cos(2\pi 4\times 10^3 t) = A\left[2\cos(2\pi\frac{200}{\pi}t) + 4\sin(2\pi\frac{250}{\pi}t + \frac{\pi}{3})\right]\cos(2\pi 4\times 10^3 t) \\
&= A\cos(2\pi(4\times 10^3 + \frac{200}{\pi})t) + A\cos(2\pi(4\times 10^3 - \frac{200}{\pi})t) \\
&\quad +2A\sin(2\pi(4\times 10^3 + \frac{250}{\pi})t + \frac{\pi}{3}) - 2A\sin(2\pi(4\times 10^3 - \frac{250}{\pi})t - \frac{\pi}{3})
\end{aligned}$$

Taking the Fourier transform of the previous relation, we obtain

$$\begin{aligned}
U(f) &= A\left[\delta(f-\frac{200}{\pi}) + \delta(f+\frac{200}{\pi}) + \frac{2}{j}e^{j\frac{\pi}{3}}\delta(f-\frac{250}{\pi}) - \frac{2}{j}e^{-j\frac{\pi}{3}}\delta(f+\frac{250}{\pi})\right] \\
&\quad * \frac{1}{2}[\delta(f-4\times 10^3) + \delta(f+4\times 10^3)] \\
&= \frac{A}{2}\left[\delta(f-4\times 10^3 - \frac{200}{\pi}) + \delta(f-4\times 10^3 + \frac{200}{\pi})\right. \\
&\quad +2e^{-j\frac{\pi}{6}}\delta(f-4\times 10^3 - \frac{250}{\pi}) + 2e^{j\frac{\pi}{6}}\delta(f-4\times 10^3 + \frac{250}{\pi}) \\
&\quad +\delta(f+4\times 10^3 - \frac{200}{\pi}) + \delta(f+4\times 10^3 + \frac{200}{\pi}) \\
&\quad \left. +2e^{-j\frac{\pi}{6}}\delta(f+4\times 10^3 - \frac{250}{\pi}) + 2e^{j\frac{\pi}{6}}\delta(f+4\times 10^3 + \frac{250}{\pi})\right]
\end{aligned}$$

Figure 1 depicts the magnitude and the phase of the spectrum U(f).

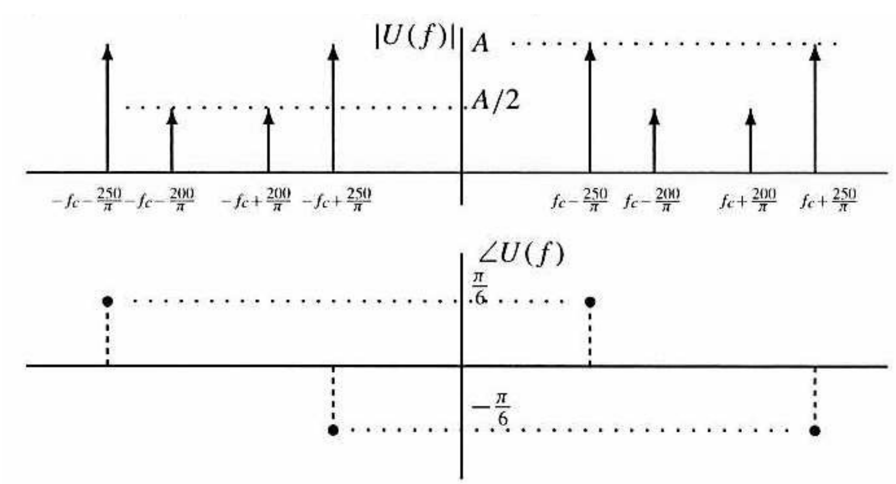

Figure 1: Figure of problem 1

Problem 2. Proakis & Salehi 3.5.

Solution:

$$u(t) = m(t) \cdot c(t) = 100[2\cos(2\pi 2000t) + 5\cos(2\pi 3000t)]\cos(2\pi f_c t)$$

$$\begin{aligned} U(f) &= \frac{100}{2}\left[\delta(f-2000) + \delta(f+2000) + \frac{5}{2}(\delta(f-3000) + \delta(f+3000))\right] \\ &\quad *[\delta(f-50000) + \delta(f+50000)] \\ &= 50\Big[\delta(f-52000) + \delta(f+48000) + \frac{5}{2}\delta(f-53000) + \frac{5}{2}\delta(f+47000) \\ &\quad +\delta(f+52000) + \delta(f+48000) + \frac{5}{2}\delta(f+53000) + \frac{5}{2}\delta(f+47000)\Big] \end{aligned}$$

A plot of the spectrum of the modulated signal is given in Figure 2.

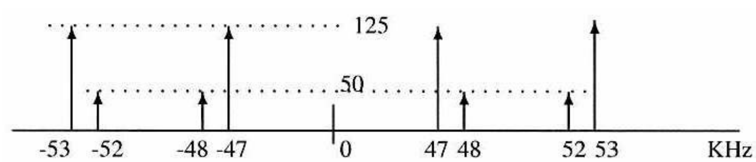

Figure 2: Figure of problem 2

Problem 3. Proakis & Salehi 3.6.

Solution: The mixed signal y(t) is given by

$$y(t) = u(t) \cdot x_L(t) = Am(t)\cos(2\pi f_c t)\cos(2\pi f_c t + \theta) = \frac{A}{2}m(t)[\cos(2\pi 2 f_c t + \theta) + \cos(\theta)]$$

The lowpass filter will cut-off the frequencies above W, where W is the bandwidth of the message signal m(t). Thus, the output of the lowpass filter is

$$z(t) = \frac{A}{2}m(t)\cos(\theta)$$

If the power of m(t) is P_M, then the power of the output signal z(t) is $P_out = P_M \frac{A^2}{4}\cos^2(\theta)$. The power of the modulated signal $u(t) = Am(t)\cos(2\pi f_c t)$ is $P_u = \frac{A^2}{4}\cos^2(\theta)$. Hence,

$$\frac{P_{out}}{P_u} = \frac{1}{2}\cos^2(\theta)$$

A plot of $\frac{P_{out}}{P_u}$ for $0 \leq \theta \leq \pi$ is given in Figure 3.

Problem 4. Proakis & Salehi 3.15.

Solution: 1) The modulated signal is written as

$$\begin{aligned} u(t) &= 100(2\cos(2\pi 10^3 t) + \cos(2\pi 3 \times 10^3 t))\cos(2\pi f_c t) \\ &= 200\cos(2\pi 10^3 t)\cos(2\pi f_c t) + 100\cos(2\pi 3 \times 10^3 t)\cos(2\pi f_c t) \\ &= 100[\cos(2\pi(f_c + 10^3)t) + \cos(2\pi(f_c - 10^3)t)] \\ &\quad +50[\cos(2\pi(f_c + 3 \times 10^3)t) + \cos(2\pi(f_c - 3 \times 10^3)t)] \end{aligned}$$

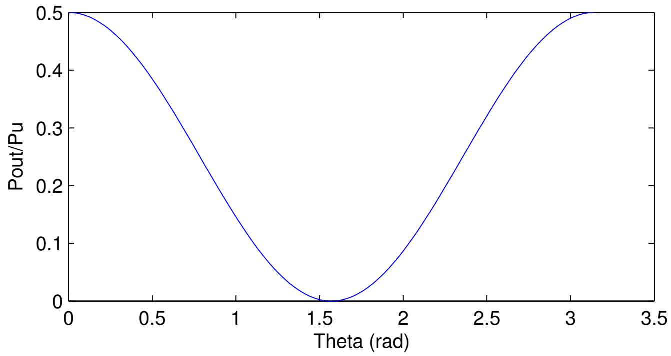

Figure 3: Figure of problem 3

Taking the Fourier transform of the previous expression, we obtain

$$\begin{aligned} U(f) &= 50\Big[\delta(f-(f_c+10^3))+\delta(f+f_c+10^3)+\delta(f-(f_c-10^3))+\delta(f+f_c-10^3)\Big] \\ &\quad +25\Big[\delta(f-f_c-3\cdot 10^3)+\delta(f+f_c+3\cdot 10^3)+\delta(f-f_c+3\cdot 10^3)+\delta(f+f_c-3\cdot 10^3)\Big] \end{aligned}$$

The spectrum of the signal is depicted in Figure 4.

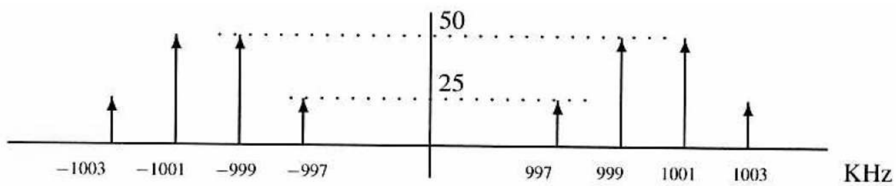

Figure 4: Figure of problem 4

2) The average power in the frequencies $f_c + 1000$ and $f_c - 1000$ is

$$P_{f_c+1000} = P_{f_c-1000} = \frac{100^2}{2} = 5000$$

The average power in the frequencies $f_c + 3000$ and $f_c - 3000$ is

$$P_{f_c+3000} = P_{f_c-3000} = \frac{50^2}{2} = 1250$$

Problem 5. Proakis & Salehi 3.21.

Solution: 1) The lowpass equivalent transfer function of the system is

$$H_l(f) = 2u_{-1}(f+f_c)H(f+f_c) = 2\begin{cases} \frac{1}{W}f+\frac{1}{2} & |f| \le \frac{W}{2} \\ 1 & \frac{W}{2} \le f \le W \end{cases}$$

Taking the inverse Fourier transform, we obtain

$$h_l(t) = \mathcal{F}^{-1}[H_1(f)] = \int_{-W/2}^{W} H_1(f)e^{j2\pi ft}df = 2\int_{-W/2}^{W/2}(\frac{1}{W}f+\frac{1}{2})e^{j2\pi ft}df + 2\int_{W/2}^{W} e^{j2\pi ft}df$$

$$
\begin{aligned}
&= \frac{2}{W}\left(\frac{1}{j2\pi t} f e^{j2\pi f t} + \frac{1}{4\pi^2 t^2} e^{j} 2\pi f t\right)\Bigg|_{-W/2}^{W/2} + \frac{1}{j2\pi t} e^{j2\pi f t}\Bigg|_{-W/2}^{W/2} + \frac{2}{j2\pi t} e^{j2\pi f t}\Bigg|_{W/2}^{W} \\
&= \frac{1}{j\pi t} e^{j2\pi W t} + \frac{j}{\pi^2 t^2 W} \sin(\pi W t) \\
&= \frac{j}{\pi t}[\mathrm{sinc}(Wt) - e^{j2\pi W t}]
\end{aligned}
$$

2) An expression for the modulated signal is obtained as follows

$$
\begin{aligned}
u(t) &= \mathrm{Re}\left[(m(t) * h_l(t))\, e^{j2\pi f_C t}\right] = \mathrm{Re}\left[\left(m(t) * \frac{j}{\pi t}(\mathrm{sinc}(Wt) - e^{j2\pi W t})\right) e^{j2\pi f_c t}\right] \\
&= \mathrm{Re}\left[\left(m(t) * \frac{j}{\pi t}\mathrm{sinc}(Wt)\right) e^{j2\pi f_c t} + \left(m(t) * \frac{1}{j\pi t} e^{j2\pi W t}\right) e^{j2\pi f_c t}\right]
\end{aligned}
$$

Note that

$$
\mathcal{F}\left[m(t) * \frac{1}{j\pi t} e^{j2\pi W t}\right] = -M(f)\mathrm{sgn}(f - W) = M(f)
$$

since $\mathrm{sgn}(f - W) = -1$ for $f < W$. Thus,

$$
\begin{aligned}
u(t) &= \mathrm{Re}\left[\left(m(t) * \frac{j}{\pi t}\mathrm{sinc}(Wt)\right) e^{j2\pi f_c t} + m(t) e^{j2\pi f_c t}\right] \\
&= m(t)\cos(2\pi f_c t) - m(t) * \left(\frac{1}{\pi t}\mathrm{sinc}(Wt)\right)\sin(2\pi f_c t)
\end{aligned}
$$

Problem 6. Proakis & Salehi Computer Problem 3.1 (use Matlab).

Solution:
1) The plots are shown in figure 5. 2) The spectra are shown in figure 6. 3) The plots are shown in figures 7 and 8. The signal $m(t)$ is the product of a sinc with a rectangular pulse between 0 and t_0. In the frequency domain, the spectrum of $m(t)$ will be the convolution of a rectangular pulse, and a sinc. The "width" of the sinc will be determined by the parameter t_0. When $t_0 = 0.1$, the sinc will be wider, and we can clearly observe the ripples in the spectra. When $t_0 = 0.4$, the sinc will be narrower, and thus the ripples are smaller and less perceptible. The Matlab code is attached at the end.

Problem 7. Proakis & Salehi Computer Problem 3.2 (use Matlab).

Solution:
1) The plots are shown in figure 9
2) The spectra are shown in figure 10.
3) The plots are shown in figures 11 and 12. The signal $m(t)$ is the product of a sinc with a rectangular pulse between 0 and t_0. In the frequency domain, the spectrum of $m(t)$ will be the convolution of a rectangular pulse, and a sinc. The "width" of the sinc will be determined by the parameter t_0. When $t_0 = 0.1$, the sinc will be wider, and we can clearly observe the ripples in the spectra. When $t_0 = 0.4$, the sinc will be narrower, and thus the ripples are smaller and less perceptible.
The Matlab code is attached at the end.

Problem 8. Proakis & Salehi Computer Problem 3.6 (use Matlab).

Solution:
1) The plots are the same as in problem 7, part 1 (figure 9)
2) The original message $m(t)$ and the demodulated message $m_r(t)$ are shown in figure 13.
3) The demodulated message is similar to the transmitted message, though it is not able to accurately follow the sharp transitions at the beginning and end of the message ($t = 0$ and $t = t_0$ in the original

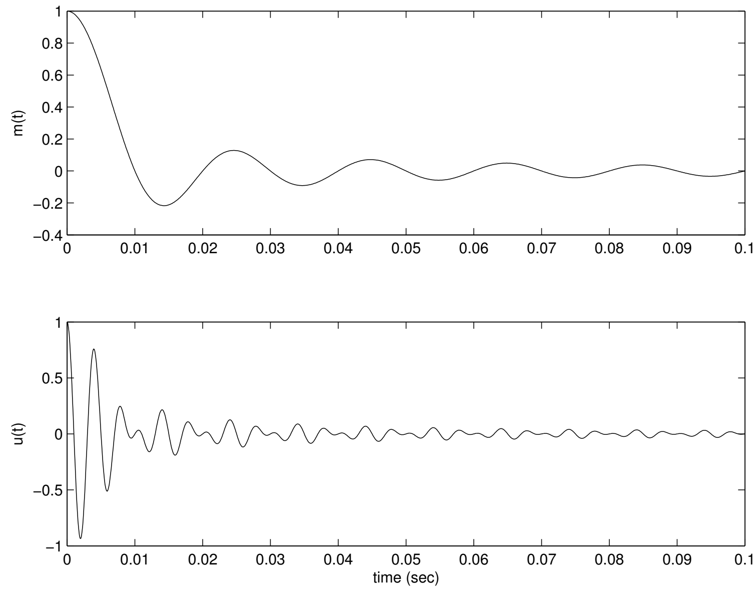

Figure 5: Figure of problem 6 (P&S 3.1.1)

message). This is because sharp transitions have high frequencies, and the lowpass filtering used in the envelope detection attenuates these frequencies.
The Matlab code is attached at the end.

Problem 9. Proakis & Salehi 4.1.

Solution: 1) Since $\mathcal{F}[\text{sinc}(400t)] = \frac{1}{400}\Pi(\frac{f}{400})$, the bandwidth of the message signal is $W = 200$ and the resulting modulation index

$$\beta(f) = \frac{k_f \max|m(t)|}{W} = \frac{k_f 10}{W} = 6 \Longrightarrow k_f = 120$$

Hence, the modulated signal is

$$u(t) = A\cos(2\pi f_c t + 2\pi k_f \int_{-\infty}^{t} m(\tau)d\tau) = 100\cos(2\pi f_c t + +2\pi 1200 \int_{-\infty}^{t} \text{sinc}(400\tau)d\tau)$$

2) The maximum frequency deviation of the modulated signal is

$$\Delta f_{\max} = \beta_f W = 6 \times 200 = 1200$$

3) Since the modulated signal is essentially a sinusoidal signal with amplitude $A = 100$, we have

$$P = \frac{A^2}{2} = 5000$$

4) Using Carson's rule, the effective bandwidth of the modulated signal can be approximated by

$$B_c = 2(\beta_f + 1)W = 2(6+1)200 = 2800\text{Hz}$$

Problem 10. Proakis & Salehi 4.4.

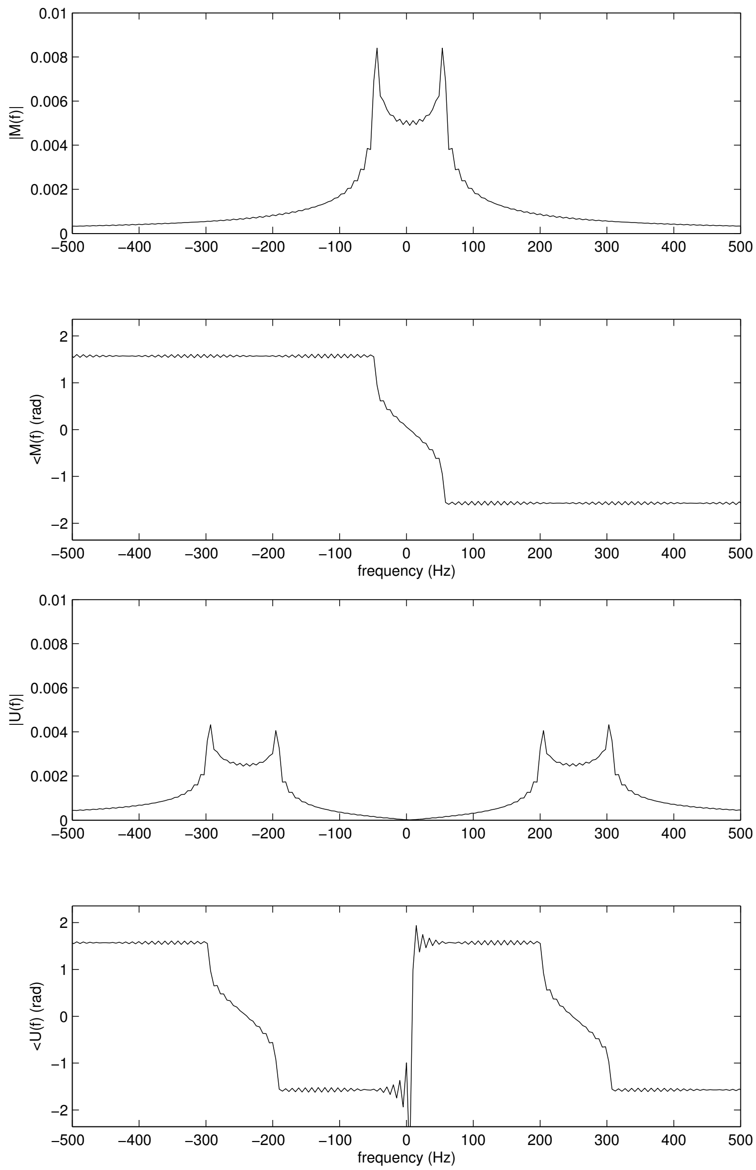

Figure 6: Figure of problem 6 (P&S 3.1.2)

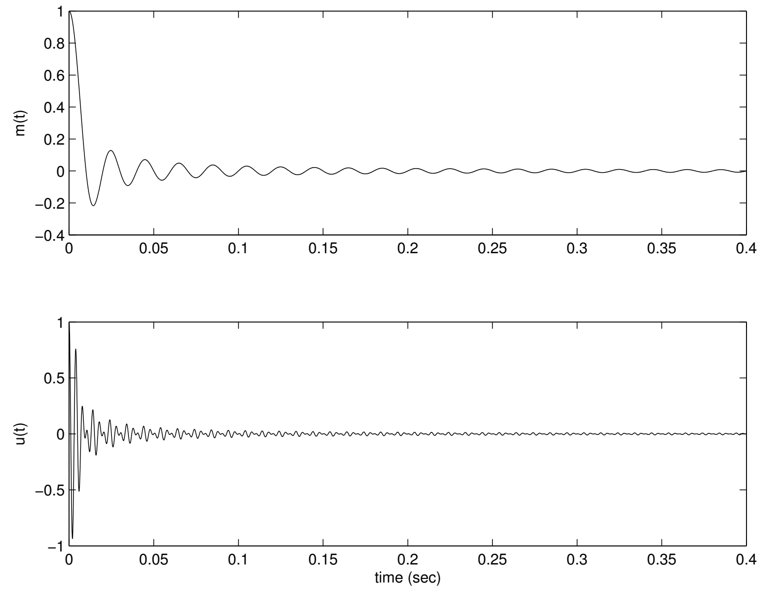

Figure 7: Figure of problem 6 (P&S 3.1.3)

Solution: 1) Since an angle modulated signal is essentially a sinusoidal signal with constant amplitude, we have

$$P = \frac{A_c^2}{2} \Longrightarrow P = \frac{100^2}{2} = 5000$$

The same result is obtained if we use the expansion

$$u(t) = \sum_{n=-\infty}^{\infty} A_c J_n(\beta)\cos(2\pi(f_c + nf_m)t)$$

along with the identity

$$J_0^2(\beta) + \sum_{n=1}^{\infty} J_n^2(\beta) = 1$$

2) The maximum phase deviation is

$$\Delta\phi_{\max} = |4\sin(2000\pi t)| = 4$$

3) The instantaneous frequency is

$$f_i = f_c + \frac{1}{2\pi}\frac{d}{dt}\phi(t) = f_c + \frac{4}{2\pi}\cos(2000\pi t)2000\pi = f_c + 4000\cos(2000\pi t)$$

Hence, the maximum frequency deviation is

$$\Delta f_{\max} = \max|f_i - f_c| = 4000$$

4) The angle modulated signal can be interpreted both as a PM and an FM signal. It is a PM signal with phase deviation constant $k_p = 4$ and message signal $m(t) = \sin(2000\pi t)$ and it is a FM signal with frequency deviation constant $k_f = 4000$ and message signal $m(t) = \cos(2000\pi t)$.

Problem 11. Proakis & Salehi 4.9.

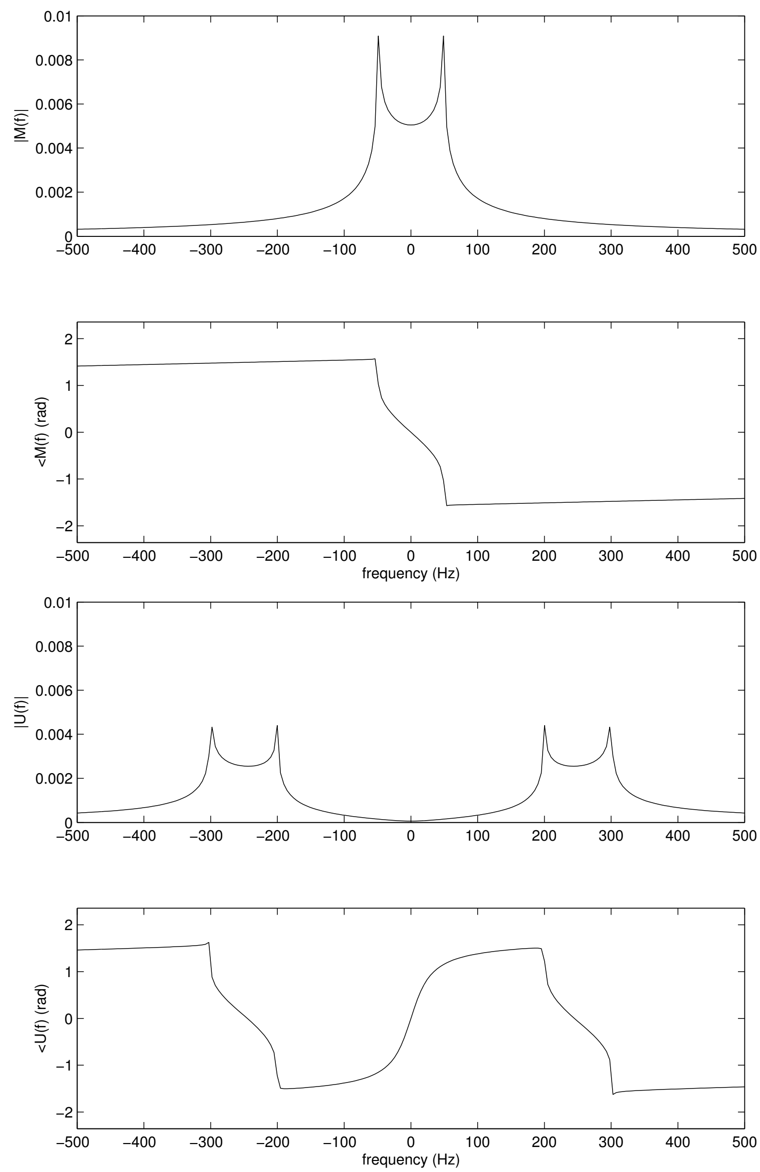

Figure 8: Figure of problem 6 (P&S 3.1.3)

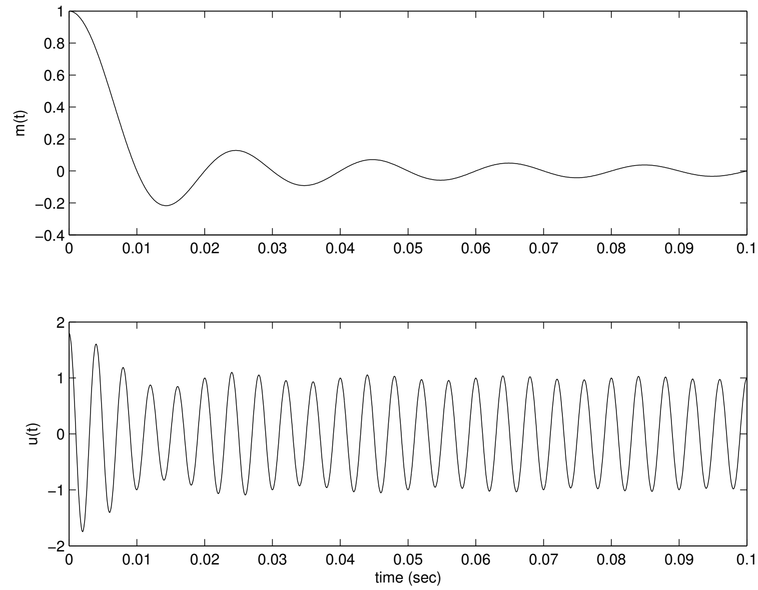

Figure 9: Figure of problem 7 (P&S 3.2.1)

Solution: 1) The modulated index is

$$\beta = \frac{k_f \max|m(t)|}{f_m} = \frac{\Delta f_{\max}}{f_m} = \frac{20 \times 10^3}{10^4} = 2$$

The modulated signal u(t) has the form

$$u(t) = \sum_{n=-\infty}^{\infty} A_c J_n(\beta)\cos(2\pi(f_c + nf_m)t + \phi_n) = \sum_{n=-\infty}^{\infty} 100 J_n(2)\cos(2\pi(10^8 + n10^4)t + \phi_n)$$

The power of unmodulated carrier signal is $P = \frac{100^2}{2} = 5000$. The power in the frequency component $f = f_c + k10^4$ is

$$P_{f_c+kf_m} = \frac{1000^2 J_k^2(2)}{2}$$

Index k	$J_k(2)$	Frequency Hz	Amplitude $100J_k(2)$	Power $P_{f_c+kf_m}$
0	.2239	10^8	22.39	250.63
1	.5767	$10^8 + 10^4$	57.67	1663.1
2	.3528	$10^8 + 2 \times 10^4$	35.28	622.46
3	.1289	$10^8 + 3 \times 10^4$	12.89	83.13
4	.0340	$10^8 + 4 \times 10^4$	3.40	5.7785

The above table shows the values of $J_k(2)$, the frequency $f_c + kf_m$, the amplitude $100J_k(2)$ and the power $P_{f_c+kf_m}$ for various values of k. As it is observed from the table the signal components that have a power level greater than 500 (= 10% of the power of the unmodulated signal) are those with frequencies $10^8 + 10^4$ and $10^8 + 2 \times 10^4$. Since $J_n^2(\beta) = J_{-n}^2(\beta)$ it is conceivable that the signal components with frequency $10^8 - 10^4$ and $10^8 - 2 \times 10^4$ will satisfy the condition of minimum power level. Hence, there are four signal components that have a power of at least 10 % of the power of the unmodulated signal. The components with frequencies $10^8 + 10^4$, $10^8 - 10^4$ have an amplitude equal to 57.67, whereas the signal components with frequencies $10^8 + 2 \times 10^4$, $10^8 - 2 \times 10^4$ have an amplitude equal to 35.28.

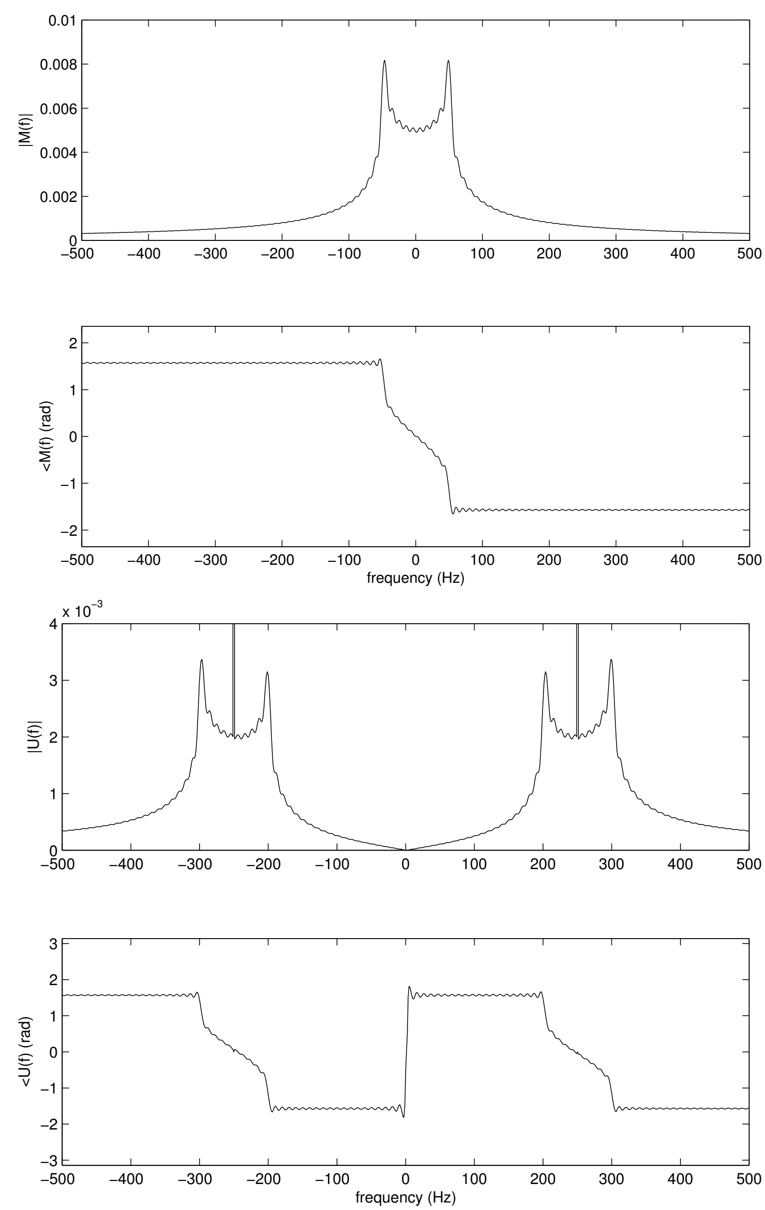

Figure 10: Figure of problem 7 (P&S 3.2.2)

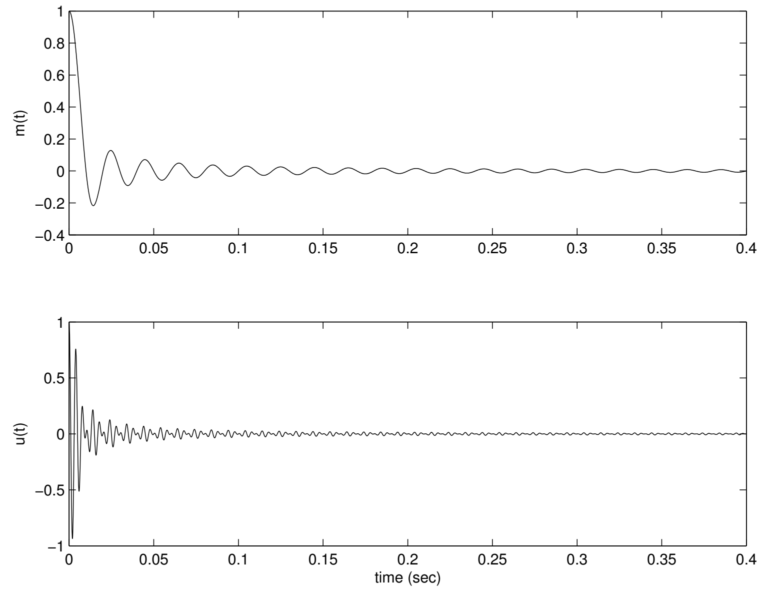

Figure 11: Figure of problem 7 (P&S 3.2.3)

2) Using Carson's rule, the approximate bandwidth of the FM signal is

$$B_c = 2(\beta + 1)f_m = 6 \times 10^4 \text{ Hz}$$

Problem 12. Proakis & Salehi 4.12.

Solution: 1) Assuming that $u(t)$ is an FM signal it can be written as

$$u(t) = 100\cos\left[2\pi f_c t + 2\pi k_f \int_{-\infty}^{\infty} \alpha\cos(2\pi f_m \tau)d\tau\right] = 100\cos\left[2\pi f_c t + \frac{k_f \alpha}{f_m}\sin(2\pi f_m t)\right]$$

Thus, the modulation index is $\beta_f = \frac{k_f \alpha}{f_m} = 4$ and the bandwidth of the transmitted signal

$$B_{FM} = 2(\beta_f + 1)f_m = 10\text{KHz}$$

2) If we double the frequency, then

$$u(t) = 100\cos(2\pi f_c t + 4\sin(2\pi 2 f_m t))$$

Using the same argument as before we find that $\beta_f = 4$ and

$$B_{FM} = 2(\beta_f + 1)2f_m = 20\text{KHz}$$

3) If the signal $u(t)$ is PM modulated, then

$$\beta_p = \Delta\phi_{\max} = \max[4\sin(2\pi f_m t)] = 4$$

The bandwidth of the modulated signal is

$$B_{PM} = 2(\beta_p + 1)f_m = 10\text{KHz}$$

4) If f_m is doubled, then $\beta_p = \Delta\phi_{\max}$ remains unchanged whereas

$$B_{PM} = 2(\beta_p + 1)2f_m = 20\text{KHz}$$

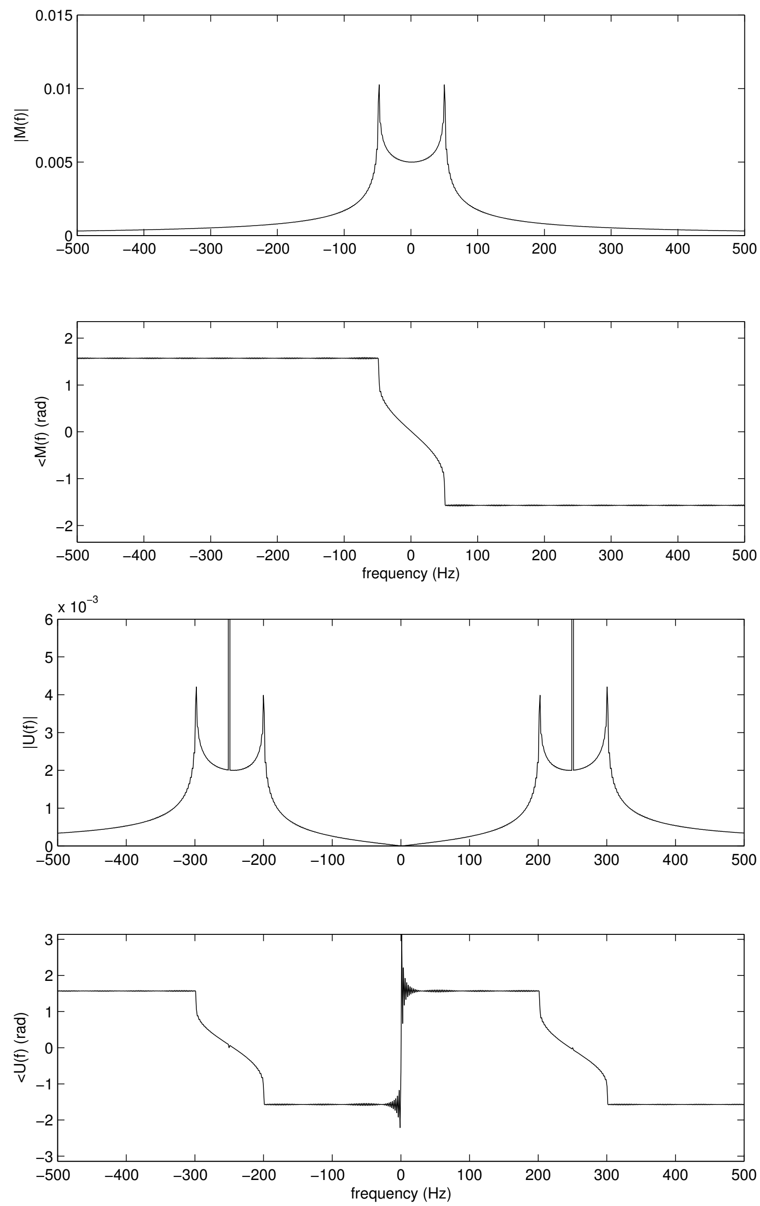

Figure 12: Figure of problem 7 (P&S 3.2.3)

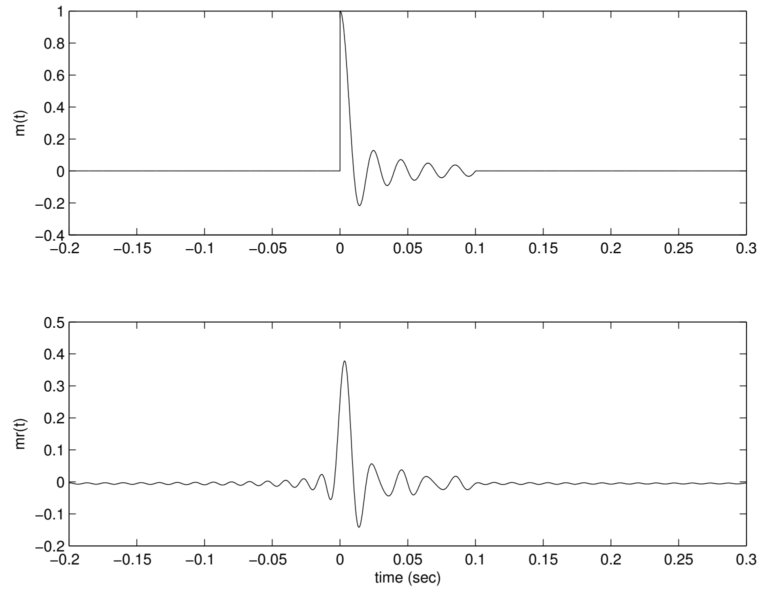

Figure 13: Figure of problem 8 (P&S 3.6.2)

Problem 13. Proakis & Salehi Computer Problem 4.1 (use Matlab).

Solution:
1) The plots are shown in figure 14.
2) The plot is shown in figure 15.
3) The plots are shown in figure 16.
4) The bandwidth of $m(t)$ is $W = 3/t_0 = 20$ Hz. The modulation index is $\beta = k_f \max|m(t)|/W = 5$. From Carson's rule, $B_c = 2(\beta + 1)W = 240$ Hz. From the plot, we can observe that this is a good approximation for the bandwidth of $u(t)$.
The Matlab code is attached at the end.

Problem 14. Proakis & Salehi Computer Problem 4.2 (use Matlab).

Solution:
1) The plots are shown in figure 17.
2) The plot is shown in figure 18.
3) The plots are shown in figure 19.
4) The plots are shown in figure 20.
The Matlab code is attached at the end.

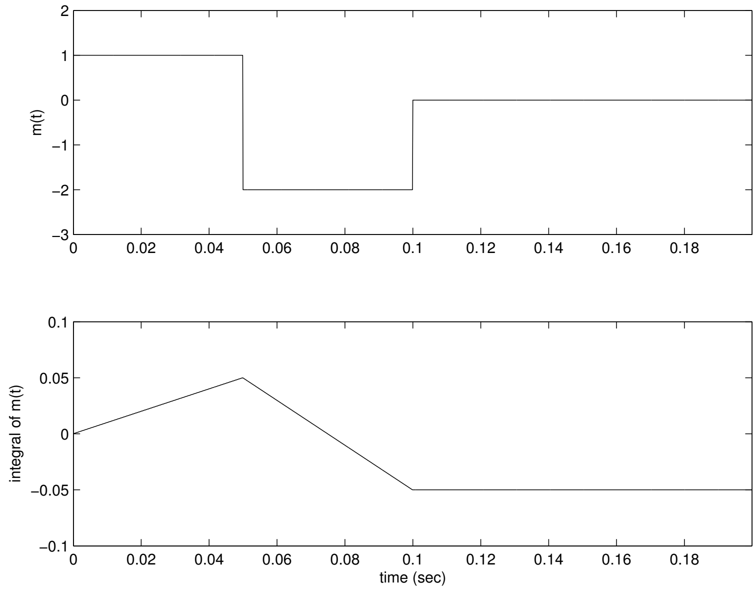

Figure 14: Figure of problem 13 (P&S 4.1.1)

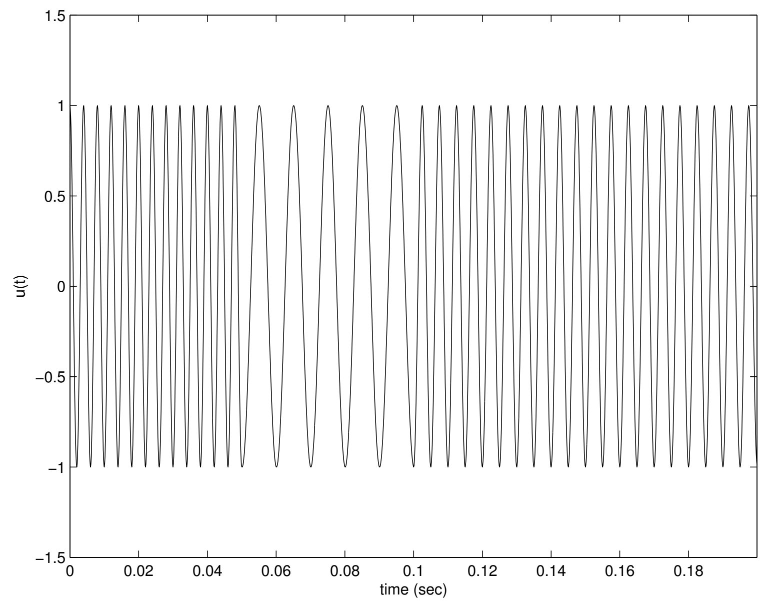

Figure 15: Figure of problem 13 (P&S 4.1.2)

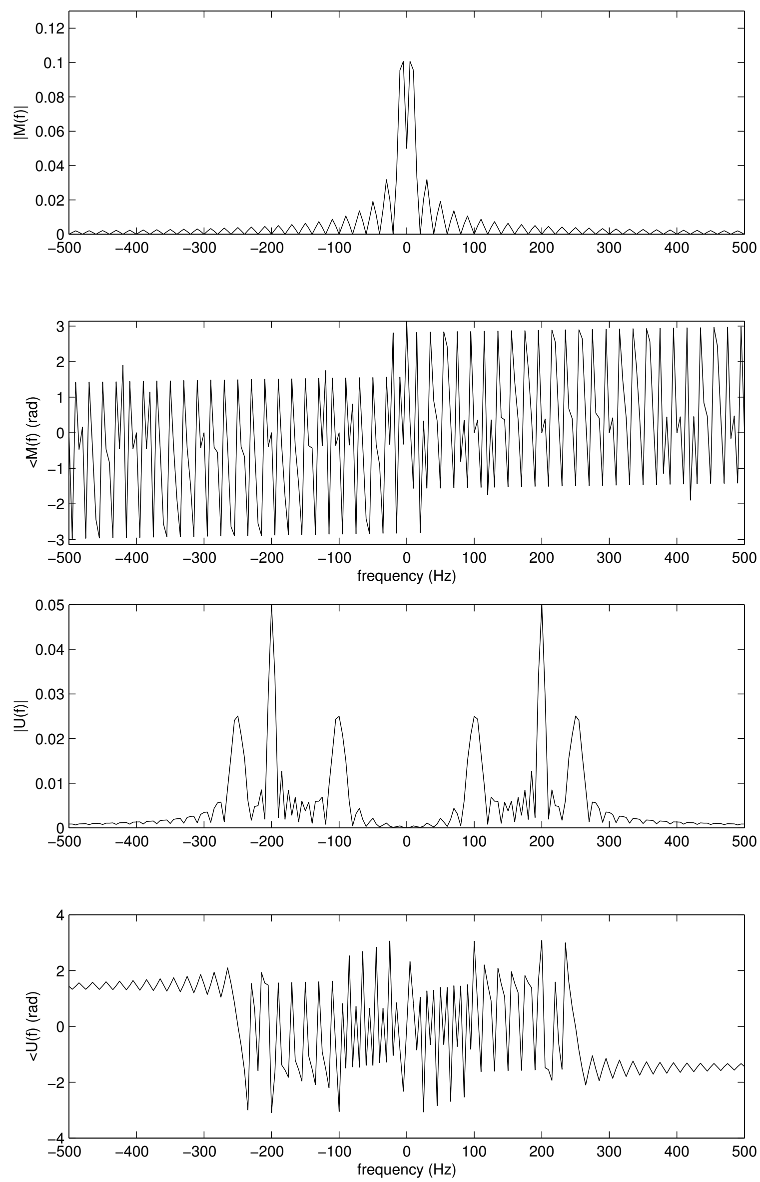

Figure 16: Figure of problem 13 (P&S 4.1.3)

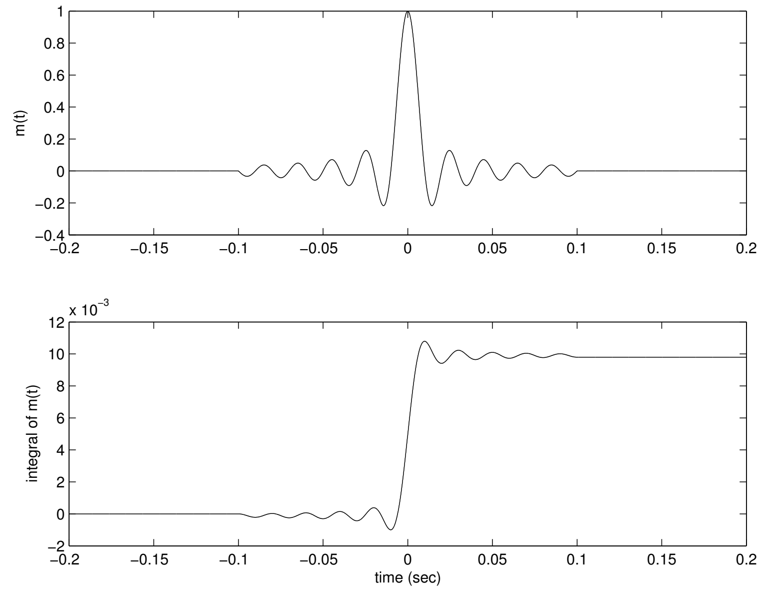

Figure 17: Figure of problem 14 (P&S 4.2.1)

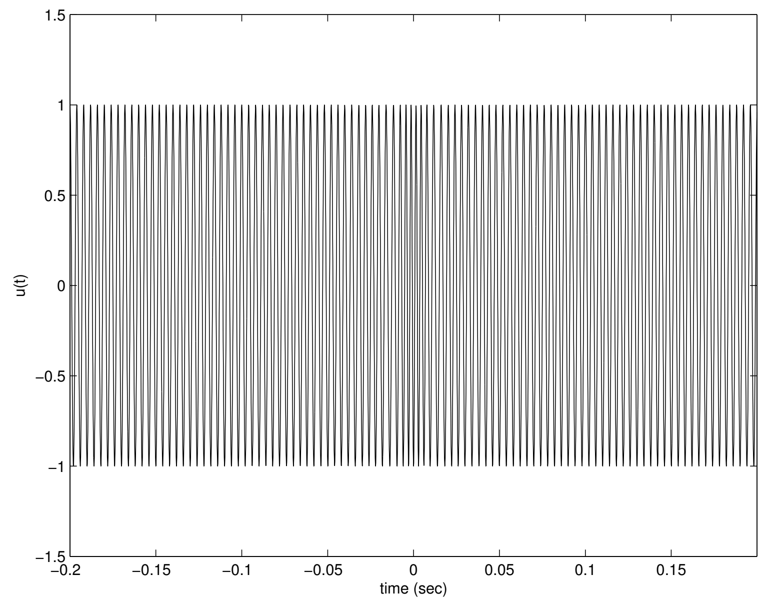

Figure 18: Figure of problem 14 (P&S 4.2.2)

Matlab code

Matlab code for problem 6:

```
%-------------------------------------------
% EE132A, Winter 2008, Homework 2
% TA: Federico Cattivelli
% Problem 6 (P&S Comp. Prob. 3.1)

ts=0.0001;   %Sampling time
Nfft=2048;   %FFT size
t0=0.1;
```

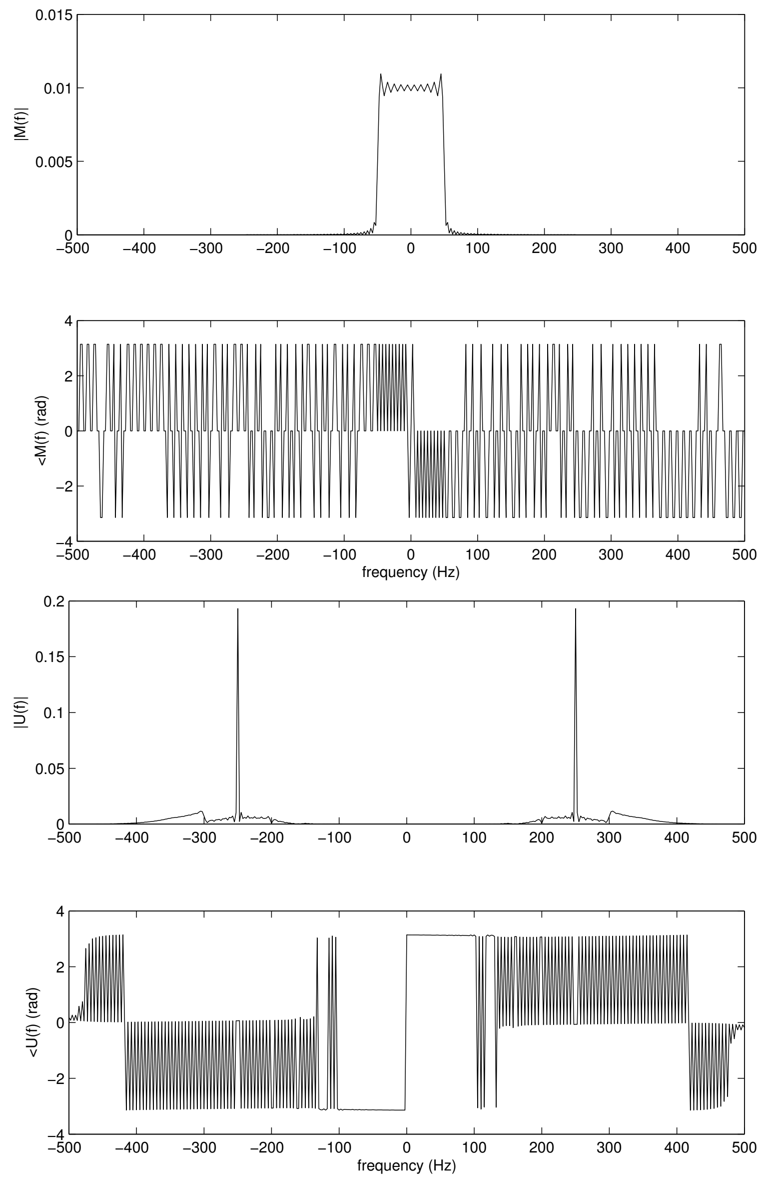

Figure 19: Figure of problem 14 (P&S 4.2.3)

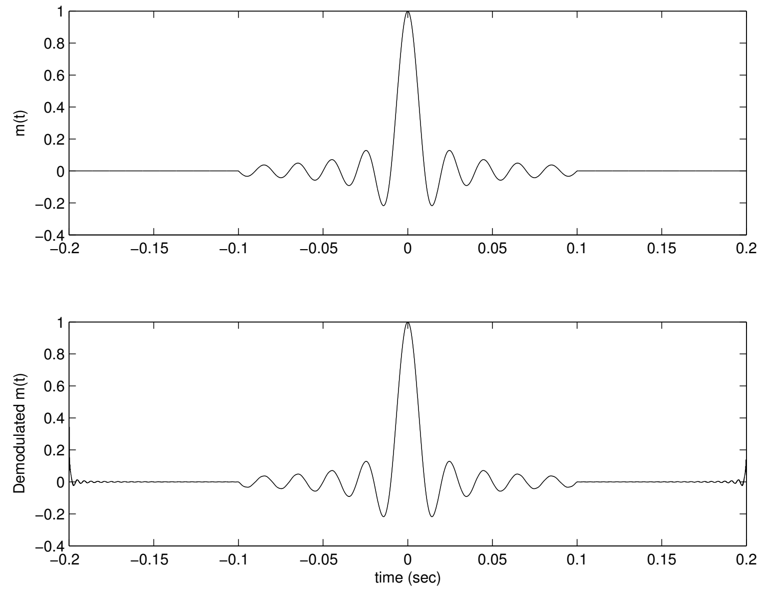

Figure 20: Figure of problem 14 (P&S 4.2.4)

```
fc=250;

t=0:ts:t0;              %Time vector
m=sinc(100*t);          %Message
c=cos(2*pi*fc*t);       %Carrier
u=m.*c;                 %DSB-SC

%Part 1
h=figure(1);
subplot(2,1,1);plot(t,m);
ylabel('m(t)');
subplot(2,1,2);plot(t,u);
ylabel('u(t)');
xlabel('time␣(sec)');
saveas(h,'prob_3_1_1','eps');      %Save figure

%Part 2
f=[-Nfft/2:Nfft/2-1]/Nfft/ts;

%Option 1: take FFT and shift
%M=fftshift(fft(m,Nfft))*ts;
%Option 2: calculate Fourier Transform by approximating convolution
M=conv(1/100*rectpuls(f/100),t0*sinc(t0*f).*exp(-j*pi*t0*f))/ts/Nfft;
M=M(length(f)/2:1:length(M)-length(f)/2);

h=figure(2);
subplot(2,1,1);plot(f,abs(M));
axis([-500 500 0 0.01])
ylabel('|M(f)|');
subplot(2,1,2);plot(f,angle(M));
axis([-500 500 -3*pi/4 3*pi/4])
ylabel('<M(f)␣(rad)')
xlabel('frequency␣(Hz)');
saveas(h,'prob_3_1_2_1','eps');      %Save figure

%Option 1: Use FFT
%U=fftshift(fft(u,Nfft))*ts;      %Take FFT and shift

%Option 2: Calculate Fourier Transform directly
Mleft=circshift(M,[0 round(-fc*ts*Nfft)]);   %Shift to the left
Mright=circshift(M,[0 round(fc*ts*Nfft)]);   %Shift to the right
U=1/2*Mleft+1/2*Mright;                      %Add

h=figure(3);
```

```
subplot(2,1,1);plot(f,abs(U));
axis([-500 500 0 0.01])
ylabel('|U(f)|');
subplot(2,1,2);plot(f,angle(U));
axis([-500 500 -3*pi/4 3*pi/4])
ylabel('<U(f)␣(rad)')
xlabel('frequency␣(Hz)');
saveas(h,'prob_3_1_2_2','eps');     %Save figure

%Part 3
t0=0.4;

t=0:ts:t0;          %Time vector
m=sinc(100*t);      %Message
c=cos(2*pi*fc*t);   %Carrier
u=m.*c;             %DSB-SC

h=figure(4);
subplot(2,1,1);plot(t,m);
ylabel('m(t)');
subplot(2,1,2);plot(t,u);
ylabel('u(t)');
xlabel('time␣(sec)');
saveas(h,'prob_3_1_3_1','eps');     %Save figure

M=fftshift(fft(m,Nfft))*ts;     %Take FFT and shift
h=figure(5);
subplot(2,1,1);plot(f,abs(M));
axis([-500 500 0 0.01])
ylabel('|M(f)|');
subplot(2,1,2);plot(f,angle(M));
axis([-500 500 -3*pi/4 3*pi/4])
ylabel('<M(f)␣(rad)')
xlabel('frequency␣(Hz)');
saveas(h,'prob_3_1_3_2','eps');     %Save figure

U=fftshift(fft(u,Nfft))*ts;     %Take FFT and shift
h=figure(6);
subplot(2,1,1);plot(f,abs(U));
axis([-500 500 0 0.01])
ylabel('|U(f)|');
subplot(2,1,2);plot(f,angle(U));
axis([-500 500 -3*pi/4 3*pi/4])
ylabel('<U(f)␣(rad)')
xlabel('frequency␣(Hz)');
saveas(h,'prob_3_1_3_3','eps');     %Save figure
```

Matlab code for problem 7:

```
%-------------------------------------------
% EE132A, Winter 2008, Homework 2
% TA: Federico Cattivelli
% Problem 7 (P&S Comp. Prob. 3.2)

ts=0.0001;   %Sampling time
Nfft=2^13;   %FFT size
t0=0.1;
fc=250;
a=0.8;

t=0:ts:t0;          %Time vector
m=sinc(100*t);      %Message
c=cos(2*pi*fc*t);   %Carrier
u=(1+a*m).*c;       %AM

%Part 1
h=figure(1);
subplot(2,1,1);plot(t,m);
ylabel('m(t)');
subplot(2,1,2);plot(t,u);
ylabel('u(t)');
xlabel('time␣(sec)');
saveas(h,'prob_3_2_1','eps');     %Save figure

%Part 2
f=[-Nfft/2:Nfft/2-1]/Nfft/ts;
```

```
%Option 1: take FFT and shift
%M=fftshift(fft(m,Nfft))*ts;
%Option 2: calculate Fourier Transform by approximating convolution
M=conv(1/100*rectpuls(f/100),t0*sinc(t0*f).*exp(-j*pi*t0*f))/ts/Nfft;
M=M(length(f)/2:1:length(M)-length(f)/2);

h=figure(2);
subplot(2,1,1);plot(f,abs(M));
axis([-500 500 0 0.01])
ylabel('|M(f)|');
subplot(2,1,2);plot(f,angle(M));
axis([-500 500 -3*pi/4 3*pi/4])
ylabel('<M(f)␣(rad)')
xlabel('frequency␣(Hz)');
saveas(h,'prob_3_2_2_1','eps');     %Save figure

%Option 1: Use FFT
%U=fftshift(fft(u,Nfft))*ts;     %Take FFT and shift

%Option 2: Calculate Fourier Transform directly
Mleft=circshift(M,[0 round(-fc*ts*Nfft)]);  %Shift to the left
Mright=circshift(M,[0 round(fc*ts*Nfft)]);  %Shift to the right
U=a/2*Mleft+a/2*Mright;                     %Add
%Approximate deltas by giving a large number
U(Nfft/2+1-round(fc*ts*Nfft))=1e10;
U(Nfft/2+1+round(fc*ts*Nfft))=1e10;

h=figure(3);
subplot(2,1,1);plot(f,abs(U));
axis([-500 500 0 0.01*a/2])
ylabel('|U(f)|');
subplot(2,1,2);plot(f,angle(U));
axis([-500 500 -pi pi])
ylabel('<U(f)␣(rad)')
xlabel('frequency␣(Hz)');
saveas(h,'prob_3_2_2_2','eps');     %Save figure

%return;

%Part 3
t0=0.4;

t=0:ts:t0;          %Time vector
m=sinc(100*t);      %Message
c=cos(2*pi*fc*t);   %Carrier
u=(1+a*m).*c;       %AM

h=figure(4);
subplot(2,1,1);plot(t,m);
ylabel('m(t)');
subplot(2,1,2);plot(t,u);
ylabel('u(t)');
xlabel('time␣(sec)');
saveas(h,'prob_3_2_3_1','eps');     %Save figure

%Option 1: take FFT and shift
%M=fftshift(fft(m,Nfft))*ts;
%Option 2: calculate Fourier Transform by approximating convolution
M=conv(1/100*rectpuls(f/100),t0*sinc(t0*f).*exp(-j*pi*t0*f))/ts/Nfft;
M=M(length(f)/2:1:length(M)-length(f)/2);

h=figure(5);
subplot(2,1,1);plot(f,abs(M));
axis([-500 500 0 0.015])
ylabel('|M(f)|');
subplot(2,1,2);plot(f,angle(M));
axis([-500 500 -3*pi/4 3*pi/4])
ylabel('<M(f)␣(rad)')
xlabel('frequency␣(Hz)');
saveas(h,'prob_3_2_3_2','eps');     %Save figure

%Option 1: Use FFT
%U=fftshift(fft(u,Nfft))*ts;     %Take FFT and shift

%Option 2: Calculate Fourier Transform directly
Mleft=circshift(M,[0 round(-fc*ts*Nfft)]);  %Shift to the left
```

```
Mright=circshift(M,[0 round(fc*ts*Nfft)]);  %Shift to the right
U=a/2*Mleft+a/2*Mright;                     %Add
%Approximate deltas by giving a large number
U(Nfft/2+1-round(fc*ts*Nfft))=1e10;
U(Nfft/2+1+round(fc*ts*Nfft))=1e10;

h=figure(6);
subplot(2,1,1);plot(f,abs(U));
axis([-500 500 0 0.015*a/2])
ylabel('|U(f)|');
subplot(2,1,2);plot(f,angle(U));
axis([-500 500 -pi pi])
ylabel('<U(f) (rad)')
xlabel('frequency (Hz)');
saveas(h,'prob_3_2_3_3','eps');    %Save figure
```

Matlab code for problem 8:

```
%-------------------------------------------
% EE132A, Winter 2008, Homework 2
% TA: Federico Cattivelli
% Problem 8 (P&S Comp. Prob. 3.6)

ts=0.0001;   %Sampling time
Nfft=2048;   %FFT size
t0=0.1;
fc=250;
a=0.8;

t=0:ts:t0;          %Time vector
m=sinc(100*t);      %Message
c=cos(2*pi*fc*t);   %Carrier
u=(1+a*m).*c;       %AM

%Part 1
%Already done in problem 3.2

%Part 2
t1=0.6;
t=-t1:ts:t1;           %Extend time vector to obtain better results
m=[zeros(1,round(t1/ts)) m zeros(1,round((t1-t0)/ts))];  %Extend message
c=cos(2*pi*fc*t);   %Carrier
u=(1+a*m).*c;       %AM

hlp=150*sinc(150*[-0.3:ts:0.3]);    %Generate lowpass filter
e=conv(hlp,abs(u))*ts;              %Filter to get envelope
e=e([length(hlp)+1000:1:length(e)-length(hlp)]);
mr=e-mean(e);                       %Subtract DC value

h=figure(1);clf;
subplot(2,1,1);
mplot=m([round(0.4/ts):1:round(0.9/ts)]);
plot([round(-0.2/ts):1:round(0.3/ts)]*ts,mplot);
ylabel('m(t)');
subplot(2,1,2);
plot([0:length(mr)-1]*ts-0.2,mr);
xlabel('time (sec)');
ylabel('mr(t)');
saveas(h,'prob_3_6_2','eps');    %Save figure
```

Matlab code for problem 13:

```
%-------------------------------------------
% EE132A, Winter 2008, Homework 2
% TA: Federico Cattivelli
% Problem 13 (P&S Comp. Prob. 4.1)

ts=0.0001;
t0=0.15;
fc=200;
kf=50;

m=[ones(1,round(t0/3/ts)) -2*ones(1,round(t0/3/ts)) zeros(1,round(2*t0/3/ts))];
t=[0:length(m)-1]*ts;
c=cos(2*pi*fc*t);
```

```
Nfft=length(m);

intm=cumsum(m)*ts;              %Approximate integral by cumulative sum

%Part 1
h=figure(1);clf;
subplot(2,1,1);
plot(t,m);
ylabel('m(t)');
axis([t(1) t(end) -3 2]);
subplot(2,1,2);
plot(t,intm);
axis([t(1) t(end) -0.1 0.1]);
xlabel('time␣(sec)');
ylabel('integral␣of␣m(t)');
saveas(h,'prob_4_1_1','eps');      %Save figure

%Part 2
u=cos(2*pi*fc*t+2*pi*kf*intm);
h=figure(2);clf;
plot(t,u);
axis([t(1) t(end) -1.5 1.5]);
ylabel('u(t)');
xlabel('time␣(sec)');
saveas(h,'prob_4_1_2','eps');      %Save figure

%Part 3
f=[-Nfft/2:Nfft/2-1]/Nfft/ts;

M=fftshift(fft(m,Nfft))*ts;
U=fftshift(fft(u,Nfft))*ts;

h=figure(3);
subplot(2,1,1);plot(f,abs(M));
axis([-500 500 0 0.13])
ylabel('|M(f)|');
subplot(2,1,2);plot(f,angle(M));
axis([-500 500 -pi pi])
ylabel('<M(f)␣(rad)')
xlabel('frequency␣(Hz)');
saveas(h,'prob_4_1_3_1','eps');      %Save figure

h=figure(4);
subplot(2,1,1);plot(f,abs(U));
axis([-500 500 0 0.05])
ylabel('|U(f)|');
subplot(2,1,2);plot(f,angle(U));
axis([-500 500 -4 4 ])
ylabel('<U(f)␣(rad)')
xlabel('frequency␣(Hz)');
saveas(h,'prob_4_1_3_2','eps');      %Save figure
```

Matlab code for problem 14:

```
%------------------------------------------
% EE132A, Winter 2008, Homework 2
% TA: Federico Cattivelli
% Problem 14 (P&S Comp. Prob. 4.2)

ts=0.0001;
t0=0.1;
fc=250;
kf=100;

t=[-0.2:ts:0.2-ts];
m=sinc(100*t).*rectpuls(t,2*t0);
c=cos(2*pi*fc*t);

Nfft=length(m);

intm=cumsum(m)*ts;              %Approximate integral by cumulative sum

%Part 1
h=figure(1);clf;
subplot(2,1,1);
plot(t,m);
```

```
ylabel('m(t)');
%axis([t(1) t(end)  2]);
subplot(2,1,2);
plot(t,intm);
%axis([t(1) t(end) -0.1 0.1]);
xlabel('time␣(sec)');
ylabel('integral␣of␣m(t)');
saveas(h,'prob_4_2_1','eps');      %Save figure

%Part 2
u=cos(2*pi*fc*t+2*pi*kf*intm);
h=figure(2);clf;
plot(t,u);
axis([t(1) t(end) -1.5 1.5]);
ylabel('u(t)');
xlabel('time␣(sec)');
saveas(h,'prob_4_2_2','eps');      %Save figure

%Part 3
f=[-Nfft/2:Nfft/2-1]/Nfft/ts;

M=fftshift(fft(m,Nfft))*ts;
U=fftshift(fft(u,Nfft))*ts;

h=figure(3);
subplot(2,1,1);plot(f,abs(M));
axis([-500 500 0 0.015])
ylabel('|M(f)|');
subplot(2,1,2);plot(f,angle(M));
axis([-500 500 -4 4])
ylabel('<M(f)␣(rad)')
xlabel('frequency␣(Hz)');
saveas(h,'prob_4_2_3_1','eps');      %Save figure

h=figure(4);
subplot(2,1,1);plot(f,abs(U));
axis([-500 500 0 0.2])
ylabel('|U(f)|');
subplot(2,1,2);plot(f,angle(U));
axis([-500 500 -4 4 ])
ylabel('<U(f)␣(rad)')
xlabel('frequency␣(Hz)');
saveas(h,'prob_4_2_3_2','eps');      %Save figure

%Part 4
Uusb=2*fftshift(U).*[ones(1,Nfft/2) zeros(1,Nfft/2)];
ulp=ifft(Uusb).*exp(-j*2*pi*fc*[0:Nfft-1]*ts);
urec=[0 diff(unwrap(angle(ulp)))/ts/2/pi/kf];

h=figure(5);
subplot(2,1,1);plot(t,m);
%axis([-500 500 0 0.015])
ylabel('m(t)');
subplot(2,1,2);plot(t,urec);
%axis([-500 500 -4 4])
ylabel('Demodulated␣m(t)')
xlabel('time␣(sec)');
saveas(h,'prob_4_2_4','eps');      %Save figure
```